INDOOR AIR QUALITY ASSESSMENT

North/Central House
Burkland Intermediate/Goode Elementary School Complex
41 Mayflower Avenue
Middleborough, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality

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Background/Introduction

At the request of Dr. Robert Sullivan, Assistant Superintendent, Middleborough Public Schools, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH) Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Henry B. Burkland Intermediate/Mary K. Goode Elementary School Complex (BIS/GES), 41 Mayflower Avenue, Middleborough, Massachusetts. On June 2, 2004, a visit to conduct an indoor air quality assessment was made to the BIS/GES complex by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Concerns about mold and other indoor air quality issues prompted the request.

The GES and BIS are both part of a three building complex. The BIS is in the northeastern section of the complex (Map 1). The GES is in the southwestern section of the complex. Both the BIS and GES share the central building of the complex, North and Central House. Hallways connect each of the building sections to other portions of the complex. The North and Central House is the subject of this report. The BIS and GES are each be the subject of separate reports.

Methods

BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The BIS houses approximately 700 students in grades 3 to 5 and a staff of approximately 50. The GES houses approximately 530 students in grades 1 and 2 with approximately 65 staff members. The North and Central House contains classrooms and general areas that are used by students/staff in both schools. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in six of twenty-one areas surveyed, indicating adequate ventilation in the many of areas surveyed. Several classrooms were sparsely occupied and/or had windows open during the assessment, which can greatly reduce carbon dioxide levels. With increased occupancy and closed windows (e.g., during the heating season), carbon dioxide levels in classrooms would be expected to be higher.

Fresh air is supplied to classrooms by a unit ventilator (univent) system. A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. A number of univents were deactivated during the assessment (Table 1). Obstructions to airflow, such as papers and books stored on univents and items placed in front of univent returns, were seen in a number of classrooms (Picture 1). In order for univents and supply vents to provide fresh air as designed, these units must remain activated and allowed to operate while rooms are occupied. In addition, univent intakes and diffusers must remain free of obstructions.

Mechanical exhaust ventilation is powered by rooftop fans. Exhaust vent grilles are located in the ceilings of coat closets (Picture 2) or in classroom walls. Air is drawn into the classroom coat closet via undercut closet doors. The exhaust system was not drawing in a few areas, indicating that motors had either been deactivated or were non-functional (Table 1). The location of these closet vents allows them to be easily blocked by stored materials, which restricts airflow. As with the univents, exhaust vents must be activated and remain free of obstructions in order to function as designed. Without sufficient supply and exhaust ventilation, environmental pollutants can build up, leading to indoor air quality complaints.

Mechanical ventilation for the pool is provided by an air handling unit (AHU). Supply air is ducted into the pool area and distributed via air diffusers mounted on ductwork. School personnel reported that the AHU was inoperable; therefore no means to introduce fresh air was being provided. Exhaust ventilation is provided by wall mounted exhaust vents connected to roof top motors. This system was operating during the assessment.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix A.

Temperature measurements ranged from 75^{o} F to 77^{o} F, which were within the BEHA comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents and exhaust vents deactivated/obstructed).

The relative humidity measured in the building ranged from 45 to 57 percent, which was also within the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

At the time of the assessment, school department officials reported that the building had active roof leaks and that funding for roof repair was part of a planned capital repair project. Water damaged ceiling tiles were observed in a number of areas throughout the building. Water-damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered and repaired. Buckets were observed to have been placed in areas to "catch" rainwater in classroom 51 (Picture 3). Water damaged wood was observed in this area with what appeared to be mold growth (Picture 4).

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable or ND. Outdoor carbon monoxide concentrations were non-detectable or ND. Carbon monoxide levels measured in the school were also ND (Table 1).

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. . Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 43 $\mu g/m^3$. PM2.5 levels measured in the school ranged from 29 to 276 $\mu g/m^3$ (Table 1). Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors. The highest PM2.5 measurement was taken in classroom 37 (276 $\mu g/m^3$). During the assessment, classroom 37 was occupied by an assembly of more than 70 students. The increased activity of these students in this room, including movement of furniture and classroom materials to accommodate extra students and staff, likely elevated airborne levels of fine particulate.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements reported are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While TVOC levels were ND, materials containing VOCs were present in the school. Cleaning products were found on countertops and in unlocked storage cabinets beneath sinks in classrooms. Cleaning products contain chemicals that can be irritating to the eyes, nose and throat. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Conclusions/Recommendations

In view of the findings at the time of the assessment, the following recommendations are made to improve general indoor air quality:

1. Survey classroom univents to ascertain function and determine whether an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
2. Investigate noise from univent in art room 46; make adjustments/repairs as necessary.
3. Operate all ventilation systems throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy and independent of

thermostat control to maximize air exchange. To increase airflow in classrooms, set univent controls to "high".

4. Contact an HVAC engineering-firm to inspect and/or make repairs to the pool AHU.
5. Inspect rooftop exhaust motors and belts for proper function, repair and replace as necessary.
6. Remove all blockages from univents and exhaust vents to facilitate airflow.
7. Consider balancing mechanical ventilation systems every 5 years, as recommended by ventilation industrial standards (SMACNA, 1994).
8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g., throat and sinus irritations).
9. Remove water damaged/mold contaminated wood work in classroom 51. Mold contaminated materials should be removed in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (US EPA, 2001). The document is available at the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
10. Continue with plants for roof repair/replacement. Replace any water-damaged ceiling tiles, once leaks are repaired. Examine the area above and beneath these areas for

microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial. Clean areas of antimicrobial application when dry.

11. Replace any missing/damaged ceiling tiles, to prevent the egress of dirt, dust and particulate matter into classrooms.

12. Store cleaning products properly and out of reach of students. Ensure spray bottles are properly labeled in case of emergency. Remove flammable materials from classrooms and store in flammable storage locker.

13. Use the principles of integrated pest management (IPM) to rid the building. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.

14. Consider adopting the US EPA document, "Tools for Schools" (US EPA, 2000b) as a means to maintaining a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

15. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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Picture 1

Univent Return Vent Obstructed by Desk

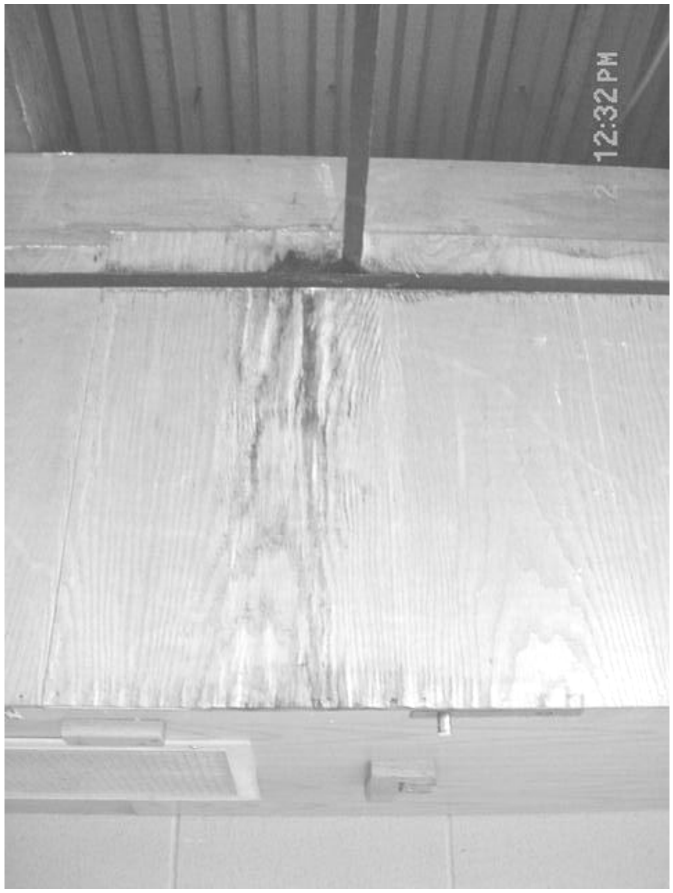
Picture 2

Coat Closet Exhaust Vent

Picture 3

Missing/Damaged Ceiling Tiles and Buckets Catching Rainwater in Classroom 51

Picture 4



Close Up of Water Damaged Wood, Dark Spots Indicate Possible Mold Growth

North/Central House Burkland/Goode School Complex **Indoor Air Results**

31 Mayflower Ave, Middleborough MA **June 2, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (Outdoors)	66	67	371	ND	ND	43	-	-	-	-	Weather Conditions: scattered clouds, winds light and variable
32	76	51	458	ND	ND	34	1	Y	Y Off	Y Off	20 occupants gone 50 min., PF, hallway DO, 2 windows open
Pool	75	66	620	ND	ND	32	20	N	N	Y ceiling/ wall	Supply vent system reportedly inoperable
33	75	57	465	ND	ND	31	0	Y	Y Off Univent	Y	1 window open, cleaning products, hallway DO
34	76	57	808	ND	ND	38	17	Y	Y Off Univent	Y	UV deactivated by occupant due to noise, 2 WD CTs, DEM, hallway DO,
35	77	56	918	ND	ND	47	22	Y	Y Off Univent	Y Closet	UV deactivated-reactivated by student with a pencil, 3 windows open
36	76	53	506	ND	ND	34	16	Y	Y Univent	Y Closet	DEM, 2 windows open, DEM, hallway DO

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

North/Central House Burkland/Goode School Complex **Indoor Air Results**

31 Mayflower Ave, Middleborough MA **June 2, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
37	77	58	821	ND	ND	276	70(+)	Y	Y Univent	Y Closet	Classroom triple occupied for assembly, hallway DO, plants
38	76	53	454	ND	ND	36	0	Y	Y	Y	DEM, PF, 2 windows open, hallway DO
39	76	55	639	ND	ND	33	23	Y	Y Univent	Y Closet	1 window open, hallway DO, exhaust vent blocked by curtain
40	76	55	778	ND	ND	37	19	Y	Y Univent	Y Closet	2 windows open, DEM, 4 WD CTs
42	76	54	411	ND	ND	35	2	Y	Y Univent	Y Off Closet	1 window open, hallway DO, 1 WD CT
Teacher's Workroom								N	Y Passive Door Vent	Y Ceiling	Hallway DO, photocopier
43	76	54	490	ND	ND	42	0	Y	Y Off Univent	Y Closet	DEM, hallway DO, 2 WD CTs

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									Supply	Exhaust	
44	77	45	516	ND	ND	29	0	Y	Y Univent	Y Closet	Hallway DO, 4 WD CTs
45 Music	77	56	802	ND	ND	33	22	Y	Y Univent	Y Closet	2 windows open, UV obstructed by furniture
46 Art	77	53	908	ND	ND	38	23	Y	Y Off Univent	Y Closet	PF, hallway door open; UV noise-possible mech. problem, hallway DO
47	76	54	453	ND	ND	32	34	Y	Y Univent	Y Closet	2 windows open, UV obstructed by clutter, exhaust blocked by curtains, PF
48	77	51	610	ND	ND	38	24	Y	Y Off Univent	Y Closet	1 window open
49	75	55	432	ND	ND	33	1	Y	Y Univent	Y Closet	2 windows open, hallway DO, plants on UV, 2 MT/AT
50	76	57	983	ND	ND	49	22	Y	Y Off Univent	Y Closet	1 window open, hallway DO, UV obstructed by furniture, CD, DEM, cleaning products

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51	75	56	649	ND	ND	40	21	Y	Y Univent	Y Closet	Active roof leaks-buckets, possible mold growth wooden wall near ceiling, 4 WD CTs, 2 MT/AT, 2 windows open, UV obstructed by furniture, hallway door open
52	75	53	540	ND	ND	32	0	Y	Y Univent	Y	3 windows open, 3 WD CTs

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